the ENERGY lab

Fire in the Ice

March 2010 Methane Hydrate Newsletter

NETL

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U.S. DEPARTMENT OF ENERGY

First Trans-Shelf-Slope Climate Study in the U.S. Beaufort Sea Completed

By Richard Coffin (NRL), Kelly Rose (NETL-DOE), Jens Greinert (NIOZ), Warren Wood (NRL-Stennis), and the Shipboard Science Party

In recent years the volume of methane released through the Arctic Ocean to the atmosphere and its potential role in the global carbon cycle has become the focus of an increasing number of studies. One such study occurred in September 2009 when the Methane in the Arctic Shelf/Slope (MITAS) expedition departed the chilly waters off the coast of Barrow, Alaska on board the U.S. Coast Guard icebreaker *Polar Sea* (Figure 1).

In comparison to other areas of the Arctic Ocean, like the Canadian-Beaufort and Svalbard regions, the sources and controls of methane flux across the U.S. Beaufort Shelf and Slope is largely unconstrained. To help address this issue, the MITAS expedition evaluated methane contributions from a variety of potential sediment and marine sources by examining how much methane is making its way from the subsurface, through the marine filter to

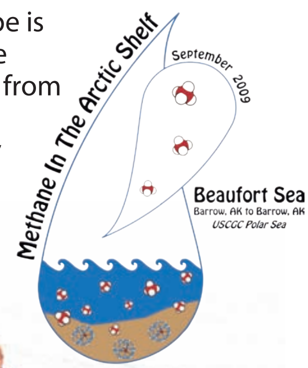

Figure 1: Seen here is the MITAS 2009 expedition science party. The expedition, led by researchers with the U.S. Naval Research Laboratory (NRL), the Royal Netherlands Institute for Sea Research (NIOZ), and the U.S. Department of Energy's National Energy Technology Laboratory (NETL), was organized with an international shipboard science team consisting of 33 scientists with the breadth of expertise necessary to meet the expedition goals.

Tests of a new marine EM survey method at Mississippi Canyon 118, Gulf of Mexico

By Karen Weitemeyer and Steven Constable, Scripps Institution of Oceanography

Although gas hydrate is an important alternative energy resource and represents a hazard to offshore drilling and development, estimates of global hydrate volume vary greatly. It is difficult to estimate bulk concentrations of hydrate using seismic methods, and drilling methods only provide samples for discrete points, offering little information about regional extent since hydrate is not always stratigraphically controlled.

Gas hydrate is, however, electrically resistive compared to the surrounding sediments, making it a prime target for electrical and electromagnetic (EM) survey methods. One such method utilizes the controlled source electromagnetic (CSEM) technique to image the bulk resistivity structure of the subsurface, providing an indication of the concentration and geometric distribution of hydrate. Although EM methods have lower resolution than seismic methods, the use of combined CSEM and seismic data can constrain the areal extent of hydrate.

In the fall of 2008, extensive data sets were collected over four prospects in the Gulf of Mexico using a standard CSEM technique with deployed seafloor receivers, and a new technique using a fixed-offset towed receiver. Presented here are the preliminary results from Mississippi Canyon 118 (MC 118; Figure 1A).

Survey methods

MC 118, a designated Minerals Management Services observatory, has large outcrops of hydrate on the seafloor but no direct evidence of hydrate at

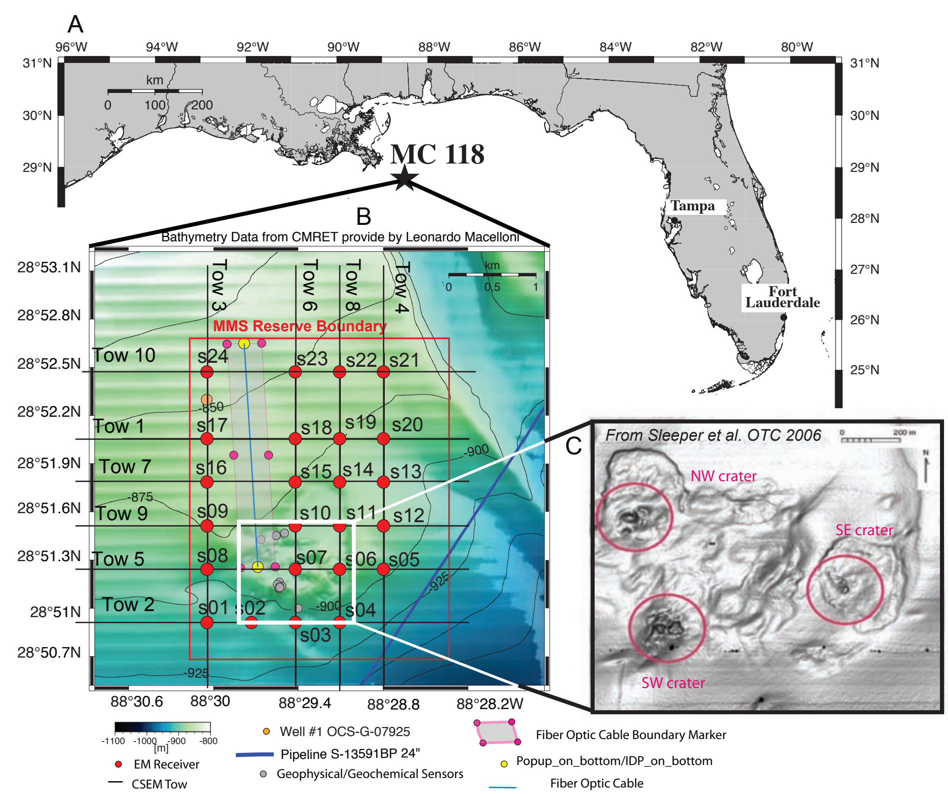

Figure 1: Location and survey map of Mississippi Canyon 118 with detail of the three craters (bathymetry provided by Leonardo Macelloni and the close up of the three craters locations is from Sleeper et al., 2006). Water depths are 800-900 m.

depth. The main area of interest is a hydrate/carbonate mound consisting of three main craters venting methane gas into the ocean at various flux rates (McGee *et al.*, 2008) (Figure 1C).

Twenty-four ocean bottom electromagnetic (OBEM) receivers were deployed in a 6 x 4 array and SUESI, Scripp's deep-towed electric field transmitter, was towed over the 10 lines forming the survey grid. SUESI "flew" at an altitude of 60 m above the seafloor to avoid already installed equipment and pipelines (Figure 1B), while transmitting a compact, broad spectrum waveform with a frequency content of 0.5 to 60 Hz. A 50 m long antenna and 200 amp transmission were used. In addition to the seafloor receivers, the "Vulcan," a new, multi-component, fixed-offset receiver (Figure 2) was towed in tandem with and 300 m behind SUESI (Figure 3).

Vulcan's development was motivated by model studies of dipping hydrate dikes, which produce signatures in the vertical electric field at short offsets, suggesting the need for more than the traditional horizontal receivers. In contrast to the seafloor instruments, for which navigation errors in the transmitter-receiver geometry become large at short ranges, the source-receiver offset for Vulcan is fixed and known. While towing at several knots the noise floor of Vulcan is comparable to the seafloor instruments when its shorted antennae are considered. Vulcan collected high quality CSEM data during our experiment.

Vulcan and OBEM apparent resistivities

We can generate apparent resistivity pseudosections for both the fixed-offset receiver (Vulcan, Figure 3, right) and the seafloor receivers (OBEM, Figure 3, left) in order to observe lateral variations in resistivity across the CSEM tow line. Although there are no analytical expressions for CSEM apparent resistivity, we can generate equivalent half-space resistivities using the Dipole1D forward modeling code of Key (2009), which allows us to model actual transmitter and receiver geometry. Different half-space responses are computed and compared to the measured electric field amplitudes to find the best half-space resistivity represented by each data point. Apparent resistivities computed this way are then projected into depth.

Vulcan apparent resistivity pseudosections were generated using the total electric field derived from the three

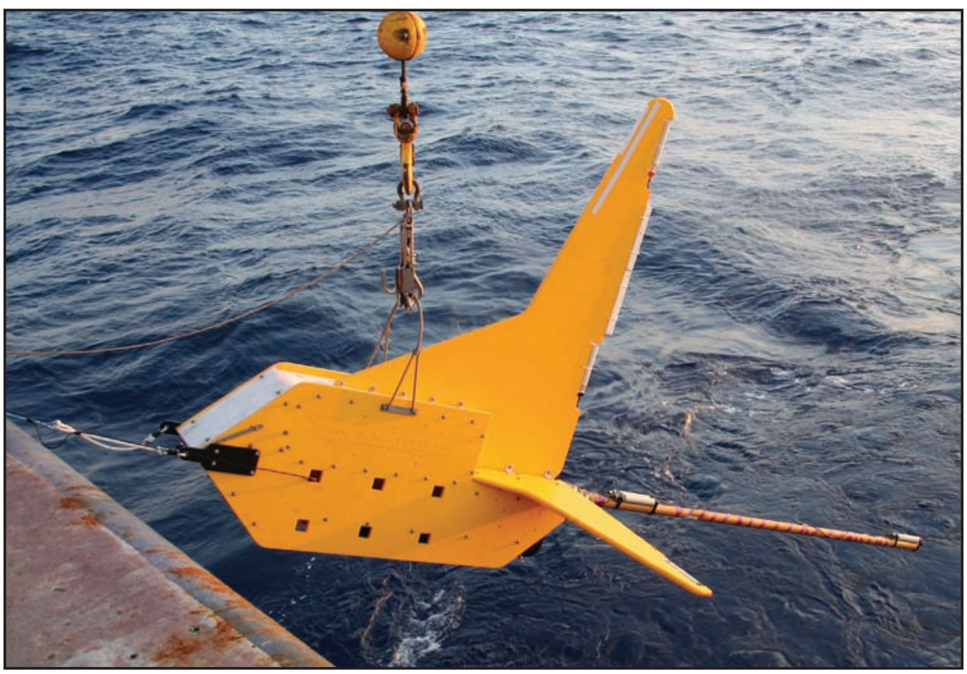

Figure 2: Photograph of the fixed-offset towed receiver (Vulcan) being deployed off the back deck of a ship. The vertical antenna is 1 m, the wingspan antenna 2 m, and the electrode spacing on the tail 'stinger' is also 2 m. It contains a 4-channel amplifier and data logger system similar to the OBEM instruments and three 10" glass floatation balls to provide neutral buoyancy. Vulcan also records output from a Paroscientific depth gauge and a heading, pitch, and roll sensor.

components measured by Vulcan (Ex, Ey, Ez) for all frequencies below 15.5 Hz. Frequencies above this are too sensitive to the geometry of the transmitter and receiver. The frequencies were projected into a depth using skin depth attenuation and then a smoothing algorithm was used to generate the image seen in Figure 4.

The OBEM pseudosections are computed at the single frequency of 6.5 Hz (Figure 5). The major axis of the polarization ellipse was used in selecting the half-space forward models that matched the recorded data, and the depth projection was derived from the source-receiver spacing.

Preliminary results

The Vulcan data (Figure 4) show MC 118 to be rather conductive with a background resistivity of 0.5-1 ohm-m and is generally featureless except at the SE crater. No constraints were placed on the intercepting tow lines and so the fact that three lines independently give a resistive body at the SE crater provides confidence that this is a geological feature (rather than an experimental artifact or navigation error). The E-W line that crosses through the SE crater is overlaid on chirp acoustic line 119 from Sleeper *et al.* (2006) for comparison with electrical resistivity. The acoustic blanking or wipeout zones at MC 118 are attributed to authigenic carbonate as well as free gas and gas hydrate (Lapham *et al.*, 2008).

Carbonate rocks are present on the floor of the SE crater, as well as a pavement of dead methanotrophic clams. There is no evidence for recent venting, suggesting that the conduit once supplying methane to these clams became blocked, perhaps due to hydrate formation (McGee *et al.*, 2009; 2008). The SE crater resistor appears to have some depth extent and the acoustic blanking there is correlated with resistive seafloor. However, acoustic blanking zones towards the SW crater is associated with the background resistivity of 1 ohm-m. The acoustic signature here is attributed to shallow carbonates (Macelloni, pers. comm.), suggesting that hydrate and carbonates, which we initially thought would be confounding electrical resistors, are in fact differentiable. Only drilling at the SE crater will confirm that the resistor there is hydrate, but it seems like a reasonable interpretation at this time.

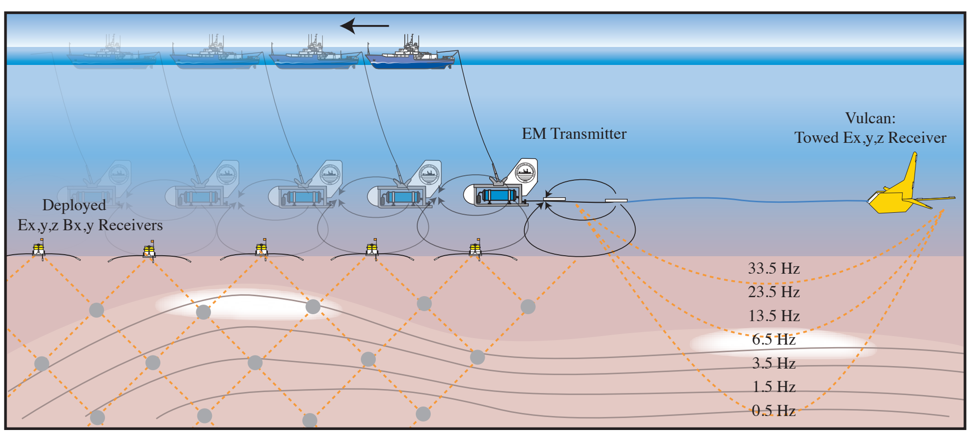

Figure 3: Building apparent resistivity pseudosections. For the OBEM receivers the midpoint between the transmitter and receiver is projected at 45 degrees below the seafloor on the assumption that larger ranges between transmitter and receiver are sensitive to deeper resistivity structure (left). For Vulcan, apparent resistivities are projected into a depth by using the skin-depth attenuation of the different frequencies measured; low frequencies have a larger skin depth and therefore map to a deeper depth than the high frequencies (right).

Figure 5 shows OBEM pseudosections, which are consistent with those from Vulcan. Three CSEM tow lines show a resistor at the SE crater, again with a background resistivity of about 1 ohm-m. Pseudosections do not provide a quantitative estimate of depth (only an inversion will resolve this), but we estimate that the OBEM data are sensitive to the top few kilometers of sediment and the Vulcan data to the top few hundred meters. Thus the slightly elevated background resistivities from the OBEM data are probably a result of sampling deeper, more compacted, sediments. Inconsistencies between the Vulcan and OBEM pseudosections in the E-W tow line crossing site 9 are likely caused by navigational errors, although they could be due to a resistor too deep to be visible by Vulcan.

In summary, CSEM data from the towed instrument Vulcan and ocean-bottom recorders have been used to discover a resistive feature under the inactive vent at the SE crater of MC 118. This resistive area is thought to be associated with the formation of hydrate within an internal plumbing system when this vent was once active. The EM data appear to have been able to distinguish between the presence of carbonate and hydrate, counter to our expectations. These early results provide a compelling argument that CSEM surveys can be used to map hydrate in the Gulf of Mexico and eventually help quantify the total volume. This survey also serves as a proof of concept for the use of Vulcan-type towed receivers in future CSEM surveys, providing a considerable reduction in survey time and cost over the use of deployed receivers.

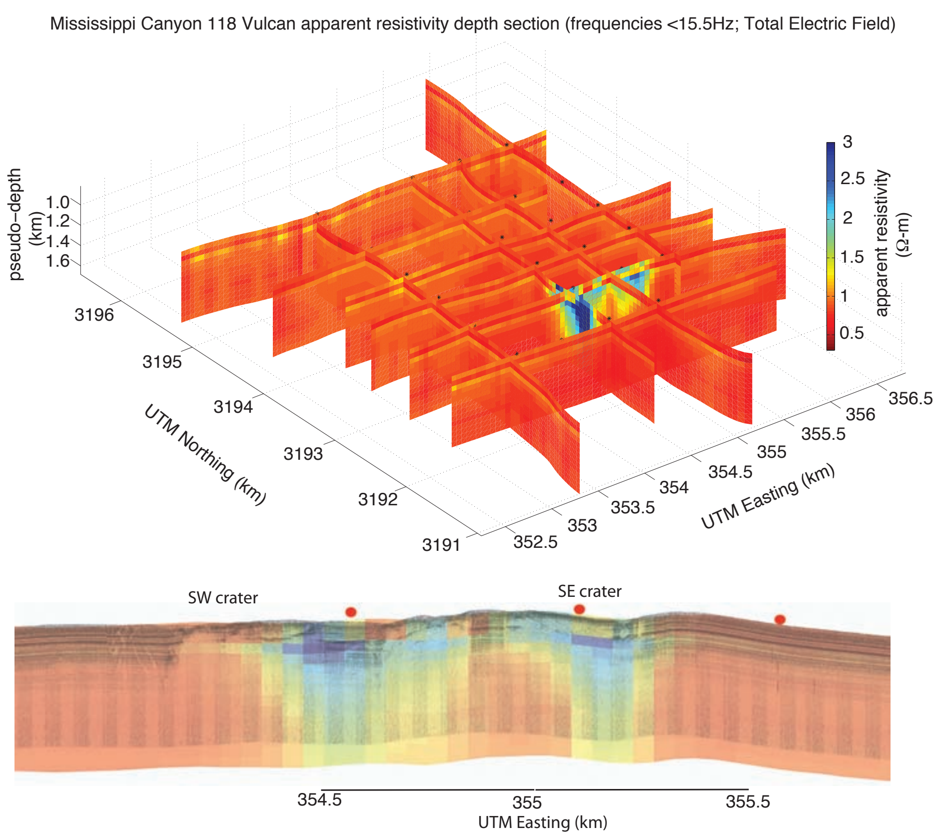

Figure 4: Apparent resistivity frequency-depth sections for Vulcan at MC 118 (top) and an EW transect from Line 5 (which crosses the SE crater) overlain on chirp acoustic data from Sleeper et al. (2006), showing the correlation of resistivity with acoustic blanking (bottom).

FURTHER READING

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Gulf of Mexico cruise website: http://marineemlab.ucsd.edu/Projects/GoMHydrate/

ACKNOWLEDGMENTS

This work was funded by NETL under contract DE-NT0005668 with additional support from CGG-Veritas, Chevron, emgs, ExxonMobil, Fugro, Shell, Statoil, WesternGeco Electromagnetics, MMS, and shiptime support from University of California.

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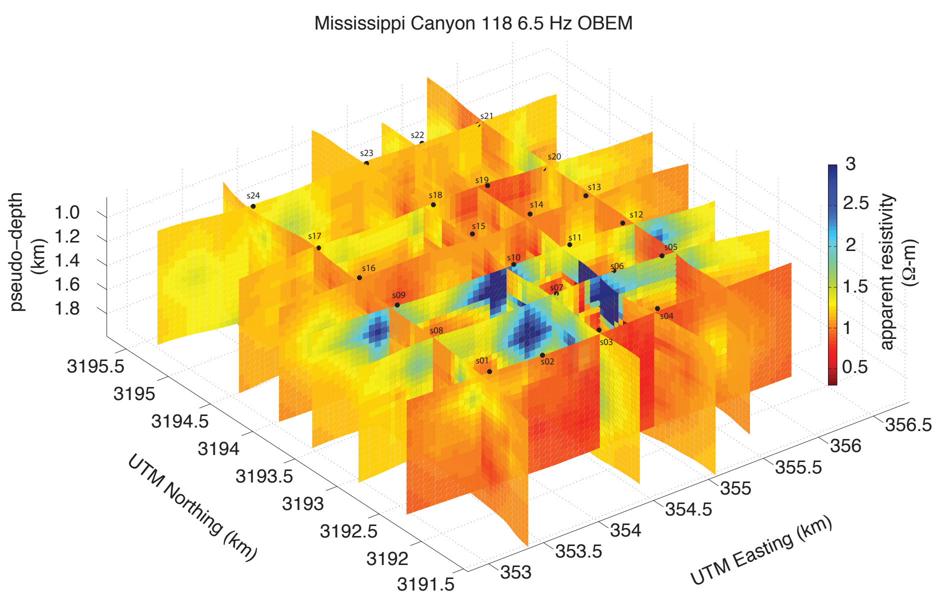

Figure 5: Mississippi Canyon 118 ocean bottom electromagnetic receiver apparent resistivity pseudosections at 6.5Hz.